MODERN GRID
INITIATIVE

Key Technology Areas

Bruce Renz, Modern Grid Initiative Team

Modernizing the Grid Midwest Regional Summit

November 16, 2006

1

Objectives

MODERN GRID INITIATIVE

- Summarize the Key Technology Areas
- Review study results to date
- Receive your feedback

Office of Electricity Delivery and Energy Reliability

Key Technology Areas

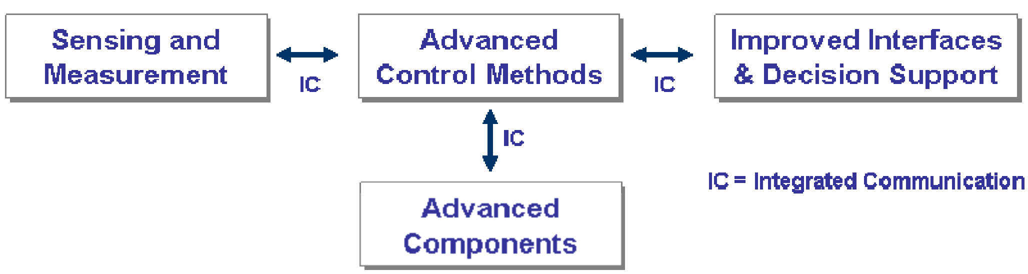
MODERN GRID INITIATIVE

- Integrated Communications (IC)
- Advanced Components (AC)
- Sensing & Measurement (SM)
- Advanced Control Methods (ACM)
- Improved Interfaces and Decision Support (DS)

Office of Electricity Delivery and Energy Reliability

Integrated Communications (IC)
The Key Technology Area Linchpin

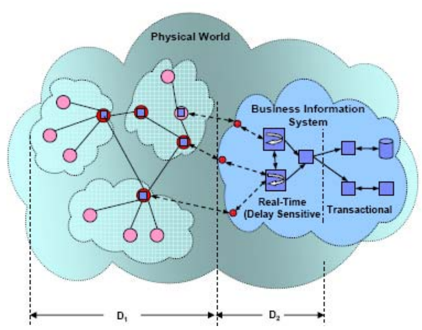
MODERN GRID INITIATIVE



Office of Electricity Delivery and Energy Reliability

An effective, fully-integrated communications infrastructure is an essential component of the modern grid:

- IC creates a dynamic, interactive “mega-infrastructure” for real-time information and power exchange
- IC allows the various intelligent electronic devices (smart meters, control centers, power electronic controllers, protection devices) and users to interact as an integrated system



IC: Key Requirements and Examples

MODERN GRID INITIATIVE

- **Open universal communication standards to enable information to be understood by a wide assortment of senders and receivers (e.g. CIM, IEEE P1901, IEC 61850…)**
- **Appropriate media to enable information to be transmitted accurately, securely and with the required throughput. Media examples include:**
  - Powerline communications (PLC and BPL)
  - Wireless (WiFi, WiMAX, 800 MHz, ,Satellite, Microwave…)
  - OPGW
  - Fiber
  - Land lines
- **Hybrid combinations of the above media, having differing capabilities, will be needed**

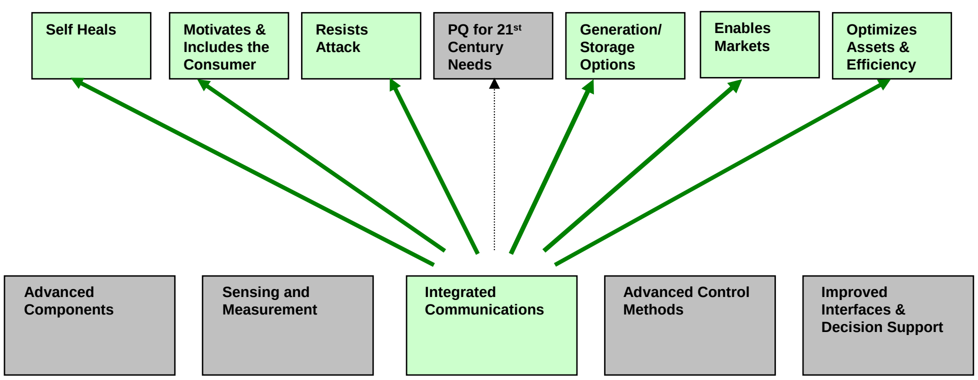
Powering the 21st Century Economy

NETL

Office of Electricity Delivery and Energy Reliability

IC: Strongly Supports 6/7 Characteristics

MODERN GRID INITIATIVE



Powering the 21st Century Economy

Office of Electricity Delivery and Energy Reliability

IC: Observed Gap

MODERN GRID INITIATIVE

- **Slow standards development process**
- **Stranded investment concerns limit deployment**
- **Little visibility of competing technologies**
- **Lack of an industry vision for IC, with such criteria as:**
  - **Ubiquity** – All potential users can take advantage of the infrastructures
  - **Integrity** – Infrastructure noticeable only when it ceases to function effectively
  - **Ease of use** – Logical, consistent and intuitive ("plug and play") rules
  - **Cost effectiveness** – Value provided is consistent with cost
  - **Standards** – Basic elements are clearly defined and stable over time
  - **Openness** – Public infrastructure available to all on a nondiscriminatory basis
  - **Security** – Infrastructure can be used without fear of interference from others
  - **Applicability** – Bandwidth will support present and future functions

Powering the 21st Century Economy

Office of Electricity Delivery and Energy Reliability

IC: Gap Closure Benefits

MODERN GRID INITIATIVE

- Achievement of the modern grid vision is fully dependent on integrated communication technologies
- Huge opportunity in reliability, quality, security, economy, safety, efficiency and environmental performance
- Standards will allow continuing development and effective deployment of communication infrastructure and other technologies
- Visibility of communication options and the benefits to users and investors will stimulate penetration and eliminate stranded investment concerns
- Deep penetration (demand) will drive prices down

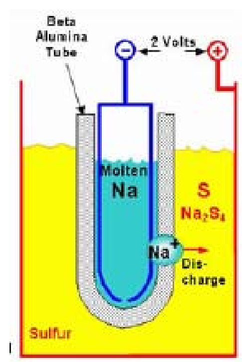
Office of Electricity Delivery and Energy Reliability

Advanced Components (AC): Overview

MODERN GRID INITIATIVE

Advanced Component devices play an active role in determining the electrical behavior of the grid.

The grid of the future will employ a wide variety of new components. These Advanced Components apply fundamental gains in materials and chemistry, superconductivity, microelectronics, and power electronics.



Office of Electricity Delivery and Energy Reliability

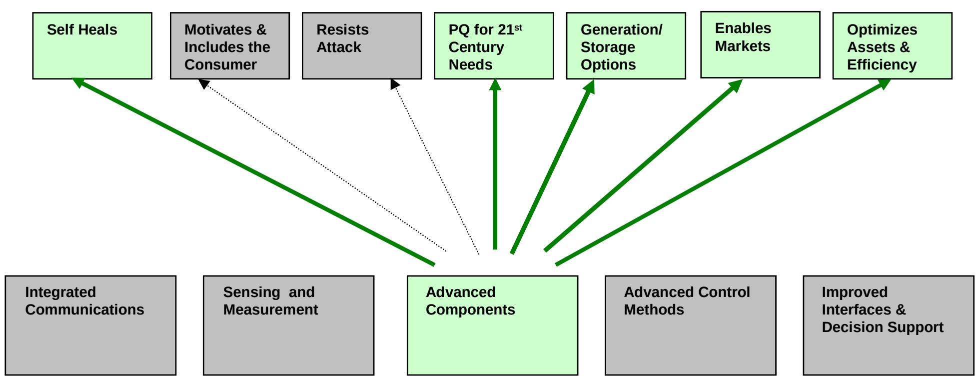
AC: Examples

MODERN GRID INITIATIVE

- Superconducting transmission cable
- Superconducting rotating machines
- Fault current limiters
- Composite conductors
- Next generation FACTS/PQ devices
- Advanced distributed generation and energy storage

AC: Strongly Supports 5/7 Characteristics

MODERN GRID INITIATIVE



Powering the 21st Century Economy

Office of Electricity Delivery and Energy Reliability

AC: Observed Gap

MODERN GRID INITIATIVE

- **While progress has been made in virtually every area, massive investment is still needed to reach the desired state**
- **Today's components are mostly the same as those employed over the past half century or more**
  - Power electronics have not been developed or employed in sufficient scale to drive down cost
  - New energy storage technologies are still in the early stage of deployment
  - Superconductivity for generation, storage, stability and power transfer has not been developed for practical application on a large scale

AC: Gap Closure Benefits

MODERN GRID INITIATIVE

- **Huge opportunity for improved reliability, quality, security, economy, safety, efficiency and environmental performance**
- **US takes the lead in a number of critical development areas**
- **Government demonstrates support of US Energy Policy**

Office of Electricity Delivery and Energy Reliability

Sensing and Measurement (SM): Overview

MODERN GRID INITIATIVE

- **New digital metering technologies including two-way communications: supporting a variety of inputs (pricing signals, time of day tariff, etc) and outputs (real-time consumption data, PQ, etc) and including the ability to remotely disconnect loads**
- **Interfaces with generators, grid operators, and customer portals: enhancing grid measurements, providing outage detection, eliminating meter estimations, providing energy theft protection, and enabling consumer choice and Demand Response**
- **Advanced sensing and measurement devices and techniques: assessing the state and condition of grid elements, establishing their capacity and failure probability in real-time, and providing the basis for advanced system protection**

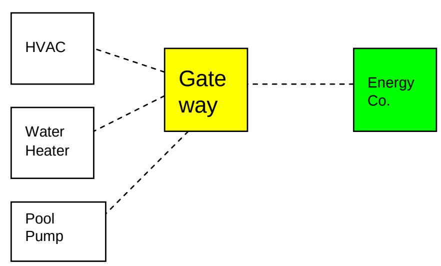
NETL

Office of Electricity Delivery and Energy Reliability

SM: Examples

MODERN GRID INITIATIVE

- Dynamic rating of transmission lines
- Wide area monitoring systems (WAMS)
- Advanced system protection
- Consumer portal
- AMI
- Splice health sensor
- Insulator leakage sensor
- EMI detection of vegetation and equipment problems
- Electronic ITs



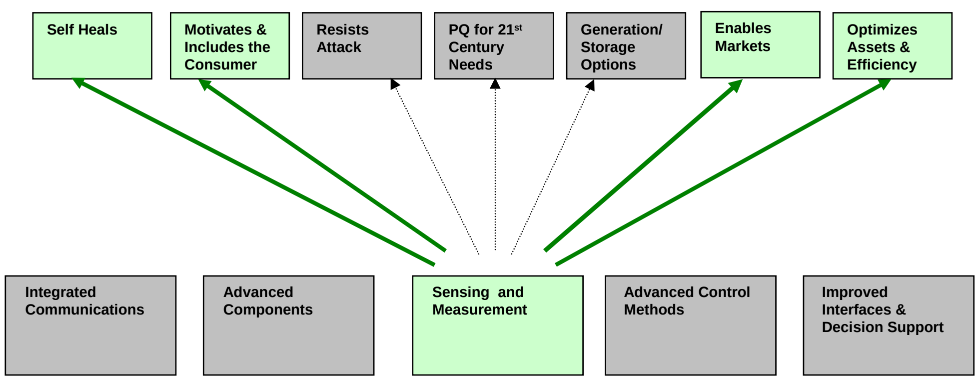
Powering the 21st Century Economy

Office of Electricity Delivery and Energy Reliability

16

SM: Strongly Support 4/7 Characteristics

MODERN GRID INITIATIVE



SM: Observed Gap

MODERN GRID INITIATIVE

- **Measurements**
  - Still a long way from each consumer having a communicating digital meter (portal)
    - Development activity underway (EPRI, CERTS, CEC…)
- **Sensing**
  - Still a long way from broad deployment of low cost advanced sensors to determine status, health and capacity of grid elements (components, circuits, systems) in real time
    - Development activity underway in such area as EMI analysis and dynamic circuit rating
    - PMUs now being integrated with standard relay packages

Office of Electricity Delivery and Energy Reliability

SM: Gap Closure Benefits

MODERN GRID INITIATIVE

- New electricity markets flourish
- Huge increase in knowledge of grid conditions
- Better planning and asset management
- New tools for operations (Demand Response)
- Consumer empowerment and involvement
- Huge opportunity in reliability, quality, security, economy, safety, efficiency and environmental performance

Bottom Line: a modern grid can't be built on a century-old measurement technology

Office of Electricity Delivery and Energy Reliability

Advanced Control Methods (ACM): Overview

MODERN GRID INITIATIVE

Broad application of computer-based algorithms that:

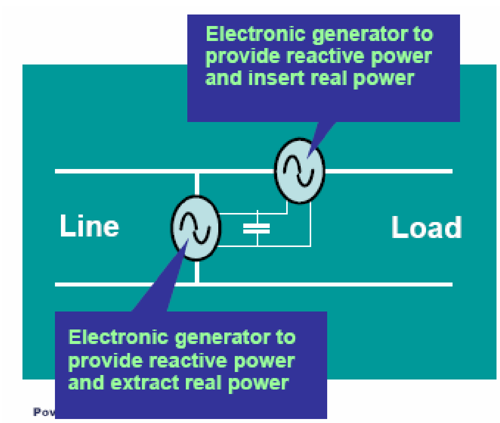
- Collect data from and monitor all essential grid components
- Analyze the data to diagnose and provide solutions from both deterministic and predictive perspectives
- Determine and take appropriate actions autonomously or through operators (depending on timing and complexity)
- Provide information and solutions to human operators
- Integrate with enterprise-wide processes and technologies

Office of Electricity Delivery and Energy Reliability

ACM: Functions Example

MODERN GRID INITIATIVE

- Smart sensors that measure power system parameters (including phasors) and monitor the actual condition of critical grid components, coupled to an integrated, high speed communications infrastructure
- Enabling advanced computer algorithms to interact with next generation control and protection devices
- Producing actions that deliver the self-healing characteristic of the modern grid

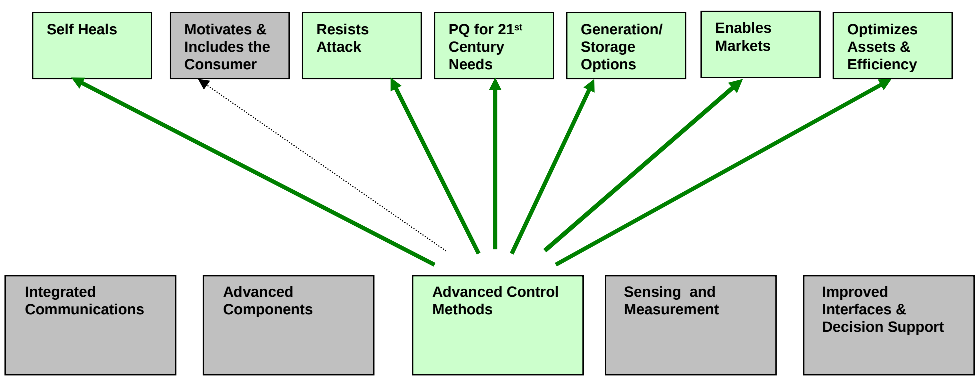


Powering the 21st Century Economy

Office of Electricity Delivery and Energy Reliability

ACM: Strongly Supports 6/7 Characteristics

MODERN GRID INITIATIVE



Powering the 21st Century Economy

NETL

Office of Electricity Delivery and Energy Reliability

ACM: Observed Gap

MODERN GRID INITIATIVE

- Vision for desired end-state is not clear
- An integrated system-wide (region-wide or greater) control perspective has not been formulated
- Widespread deployment of intelligent electronic devices has not occurred, nor has a universal interface
- Integrated communications infrastructure is missing
- Availability of data is limited
- Cost of sensors (e.g. ITs) is too high
- Slow state estimation; supercomputers not employed

ACM: Gap Closure Benefits

MODERN GRID INITIATIVE

- **Self-healing vision for the Modern Grid can be achieved**
- **Step change improvement in the effectiveness and efficiency of enterprise processes realized**
- **Huge opportunity in reliability, quality, security, economy, safety, efficiency and environmental performance**

Improved Interfaces & Decision Support (DS): Overview

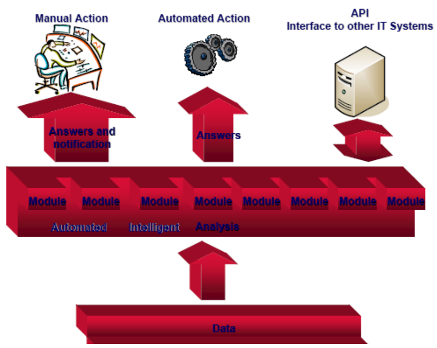
MODERN GRID INITIATIVE

- **DS technologies will transform complex power system data into information that can be understood "at a glance" by human operators**
- **Animation, color contouring, virtual reality and other data aggregation techniques will prevent "data overload" and help operators identify, analyze and act on emerging problems**

DS: Examples

MODERN GRID INITIATIVE

- **Data reduction**
  - Data reduced into the format, timeframe and technical categories most important to the operator
- **Visualization**
  - Presentation of information uses proven human factors techniques
- **Speed of comprehension**
  - Visualization methods provide information that can be rapidly converted to operator action
- **Decision support**
  - Artificial intelligence and agents identify existing, emerging, and predicted issues and provide for "what-if" analyses
- **System operator training**
  - Dynamic simulators and industry-wide certification programs significantly improve the skill sets and performance of today's operators

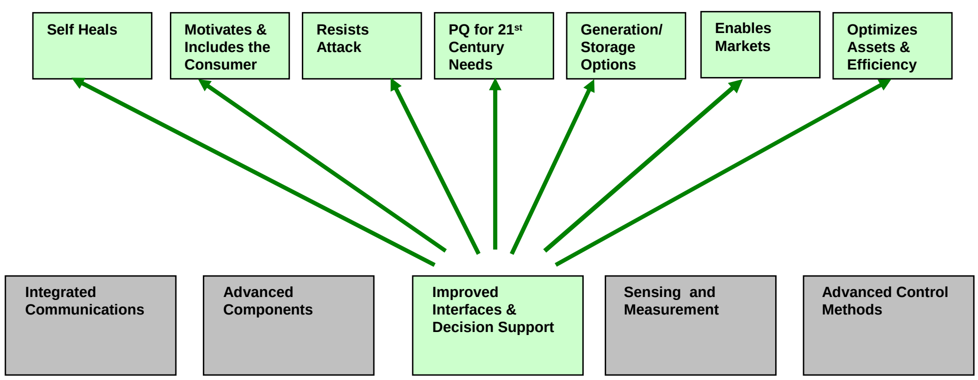


NETL

Office of Electricity Delivery and Energy Reliability

DS: Strongly Supports 7/7 Characteristics

MODERN GRID INITIATIVE



Office of Electricity Delivery and Energy Reliability

DS: Observed Gap

MODERN GRID INITIATIVE

- August 14, 2003 Blackout Task Force emphasized the need for improvements in DS
- It is more and more difficult for operators to understand the state and direction of an increasingly stressed grid
- There are no deployed supercomputers capable of instantly processing masses of data and recommending operator actions
- Operator training is not developing the advanced skills required for “real” operating environments

DS: Gap Closure Benefits

MODERN GRID INITIATIVE

- **More reliable operation of the grid and lower incidence of outages from misoperation and natural events**
- **Added options for grid stability through knowledge-assisted control of consumer loads**
- **Huge opportunity in reliability, quality, security, economy, safety, efficiency and environmental performance**

Powering the 21st Century Economy

Office of Electricity Delivery and Energy Reliability

Key Technology Areas Results to Date – Highest Impact

MODERN GRID INITIATIVE

- **Advanced Components**
  - Superconductors; power electronics
- **Sensing and Measurement**
  - Transformed metering; consumer portal
- **Integrated Communications**
  - Dynamic, interactive “mega-infrastructure” to manage a 100-fold increase in control nodes
- **Advanced Control Methods**
  - Advanced operations and protection algorithms
  - Integrated PRA in real-time operations
- **Improved Interfaces & Decision Support**
  - Semi-autonomous agent software (decision assistants)
  - Dynamic simulators for training

Office of Electricity Delivery and Energy Reliability